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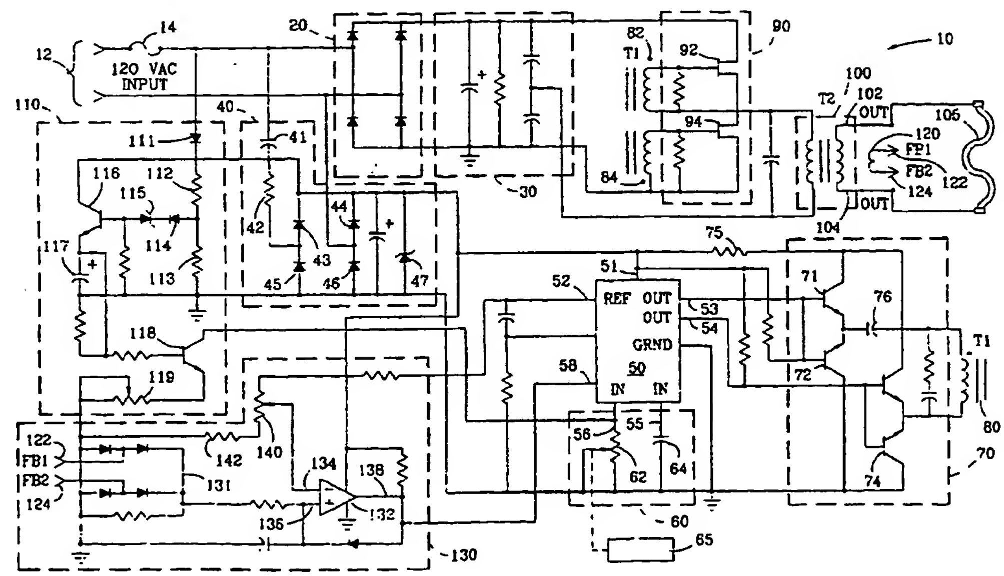

(57) Abstract

A solid state power supply circuit (10) for use with cold cathode lighting (105) which includes a converter circuit for converting input alternating electrical voltage into a high frequency, high voltage output power supplied to cold cathode lighting and a regulating circuit (110) for maintaining the output power at a constant predetermined power value independent of voltage variations of the input alternating voltage. The power supply circuit provides for convenient manual adjustment (65) of the output power on site. Overvoltage protection capabilities (130) are also available for safety.

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SOLID STATE POWER SUPPLY CIRCUIT FOR COLD CATHODE LIGHTING

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to a co-pending U.S. Patent Application, entitled "SOLID STATE POWER SUPPLY CIRCUIT FOR COLD CATHODE LIGHTING", Serial No. 08/167,227, filed December 14, 1993, and U.S. Patent Application, entitled "LIGHT BOX WITH SELECTABLY ADJUSTABLE REGULATED INTENSITY AND OVERVOLTAGE PROTECTION CIRCUITRY", which are incorporated herein by reference for all purposes as if fully set forth herein.

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a power supply for neon lighting and other cold cathode lighting, such as neon, argon and krypton gas-filled tubular lighting, and in particular, to a solid state power supply circuit with regulated output power, manually adjustable light illumination and over-voltage protection capabilities.

BACKGROUND OF THE INVENTION

Neon light tubes or other cold cathode light tubes, which include argon, neon, krypton and/or mixtures of such gases, sealed in glass tubes with and without internal phosphorescent surface coatings of various types can operate at voltages below 1000 volts, usually about 900 volts at startup and about 450 volts during normal operation. Most installations normally require high voltage power supplies, generally in excess of 1000 volts. Generally, the higher voltage power supplies are transformers rather than ballasts. In the industry, small diameter light tubes, less than about 15mm diameter, which are energized with a cold cathode have been referred to as "neon" light tubes regardless of the type of inert gases used. Larger glass tubes are generally referred to as cold cathode light tubes. One of the most common sizes is 1 inch (about 25mm) diameter and about 98 inches long. Other very large diameter light tubes may also be available. Technically, they all have cold cathodes and will be generally referred to herein as cold cathode light tubes or cold cathode lighting.

Core and coil transformers for cold cathode light tubes are available at voltages in the range of about 3,000-15,000 volts and current in the range of about 30-120 milliamperes. Higher voltages and larger current up to about 200 milliamperes have also been known for series mounted cold cathode light instruments. The optimum power and the optimum voltage and current to obtain the required power depends upon the diameter of the tubing, the length of the tubing, the type of gas or gas mixture, the gas pressure, the type of phosphorescent internal coating involved if any, and/or the operating temperature. Typically, smaller and longer light tubes require more power (i.e. higher voltage, more current or both) than for smaller and shorter light tubes.

The required high voltages and currents have been obtained in the past, primarily through the use of magnetic core and wire coil transformers having a large number of windings. The core must have low hysteresis characteristics and the copper wire must have high purity and sufficient wire diameter so that electrical resistance is low. Typically, the frequency is 60 cycles/second, which is a standard frequency for U.S. line current. Transformers of this type have been designed for stepping up standard 120 volt AC, or standard 240 volt A.C to a range of about 3000 to 15,000 volts AC. Properly wound transformers of this type are large and heavy. For example, a 3,000 volt/60 milliamp transformer can measure about 8" x 3¼" x 12¾" and can weigh about 12 lbs. A 15,000 volt/60 milliamp transformer can measure about 12" x 6" x 4½" and can weigh about 43 lbs. Such prior power supply transformers have had various drawbacks, many of which have been related to the large size and weight. There have been other specific drawbacks depending upon the particular cold cathode lighting application for which the power supply transformers are used.

By way of example, cold cathode light tubes have been used to illuminate channel letters such as those used on businesses and storefronts and the like. As the length of the light tubes increase, so does the power requirement such that the size and weight of one (or more) transformer(s) may be significant for large channel required letters. The use of more than one transformer for the same installation may allow the use of smaller transformers which will fit better into the housings for the letters, yet the costs will be high and the total weight will be about the same or greater. Letters with transformers are cumbersome and costly to install and may present significant safety hazards in overhead installations.

Internally mounted transformers are not generally available for smaller channel letters less than about 3 feet tall. As a result, small channel letters typically require external transformers and high voltage lead lines into each letter. This increases the risk of shorts, electrical shocks and other hazards. When a transformer cannot be installed so that it is protected within one of the channel letter, additional length of lead lines may be required from a remote location, such as inside a building with additional costs for each installation. There are also potential additional problems caused by the increased impedance of such long lead lines, which might lead to a different impedance value from one letter to the next in a given installation.

Also, although channel letters presently account for more than about fifty percent of the total neon light tube or cold cathode light tube market, high quality transformers are manufactured primarily in a limited number of size and shape configuration. The particular available sizes and shapes are not always adaptable for fitting within any particular channel letter design. It being noted that channel letters for identifying different businesses and for promoting different products are inherently produced as custom-made or with a wide variety of non-standard sizes.

In other applications, very large cold cathode light tubes, greater than the normal 1 inch diameter tube, may be used to continuously illuminate tunnels, corridors, escalators and substantially permanently lighted installations. These applications can require very high voltages, typically more than about 9000 volts and up to about 15,000 volts or more. The size considerations for the appropriate transformers can limit the uses of such lighting. Generally such lights have found use only in applications where a large amount of light is required and rigidity and structural support

exists both for the large light tubes and for the large transformers.

In U.S. Patent No. 5,270,910, inventor Edwin N. Kile, one of the joint inventors hereof, discloses a solid state power circuit which is both small and light weight. The circuit disclosed is particularly useful for producing a selected range of output voltages useful for light box illumination using neon tubes or small diameter cold cathode light tubes. The small size yet high power solid state power supply was advantageously incorporated into a thin light box. The disclosed power supply, while particularly useful and capable of overcoming many of the drawbacks of prior core and coil ballasts or transformer power supply circuits for light boxes, nevertheless has not been generally adapted for use in other types of cold cathode lighting, such as for powering cold cathode channel letters or for powering large cathode lights.

It has been found by applicants that application of the solid state power supplies to cold cathode lighting has both provided significant improvements and has given rise to various other areas of available improvement not previously addressed with core and coil transformer power supplies.

With cold cathode lighting, constant maximum luminosity light is normally desirable in most applications. Yet, line voltages vary from one location to another, such that a power supply which is selected for maximum effective lighting power in a particular situation, assuming one value for line voltage can result in inefficient operation or less than maximum illumination in an installation where the actual line voltage is at another value. Also, uncontrolled small line voltage fluctuations can result in substantial fluctuations in illumination. For example, less than maximum illumination or fluctuating illumination in channel letters is considered undesirable, potentially reducing sign visibility or adversely reflecting upon the

business establishment which is displaying such a dim or fluctuating brightness channel letters. Also, a poorly matched power supply can waste energy when maximum lighting efficiency is not obtained. Fluctuating input voltage can give rise to undesirable changing lighting conditions in tunnels and public transportation facilities. Constant regulation of the output power of a cold cathode power supply has not previously been adequately addressed.

Also, there has been an ever increasing public safety consciousness. The potential danger of high-voltage electricity is generally known; nevertheless, there are significant benefits for high voltage cold cathode light tube circuits over low voltage circuits or hot cathode fluorescent light tube circuits. Some of the benefits include the ability to fashion the cold cathode light tubes into desirable shapes, the capability for high illumination and the longevity of cold cathode tubes which typically have a useful life two or three times longer than hot cathode florescent tubes with the same illumination. High voltage cold cathode lighting does not require starts or impedance compensation as with ballasts and is thus a desirable commodity. There has been some concern that when a cold cathode light tube is broken while the power is turned on, the output voltage to the cold cathode increases to a level beyond the voltage for which its power supply and electrical components are normally designed. There can be a risk of shorting, arcing and overheating which can result in expensive damage and which can also result in a potential fire hazard. Further, exposed electrodes, (i.e., the cold cathode exposes by a broken glass tube) can give rise to a potential for inadvertent or accidental contact and resulting electrical shock. Replaceable fuse devices have been used to some extent with high voltage core and coil transformers. However, low cost solid state power

supply circuitry with over voltage protection capabilities has not previously been adequately provided.

Another concern which has not been previously addressed is an inability to easily adjust the intensity or illumination of cold cathode lighting. In particular, the cold cathodes themselves have such a long life that the illumination components "wear out" before the cold cathode becomes inoperative. Typically, the phosphors lose their brightness gradually over a continued period of use. Identically manufactured bulbs can have different illumination depending upon the time in service. Bulb replacement is sometimes scheduled based upon a light reduction to 65-75% of the 100 hour light output measurement. This can cause problems, for example in applications where a plurality of bulbs are used side by side. Replacement of one of several bulbs after a long period of use can result in uneven lighting with the new bulb having significantly greater illumination than the remaining bulbs. Dimmers have been available for hot cathode fluorescent lights. However, the ability to allow the user to manually adjust the illumination of cold cathode light tubes, on site, in order to achieve a consistent lighting situation has not previously been provided with a solid state cold cathode power supply.

SUMMARY OF THE INVENTION

The present invention overcomes many the problems and drawbacks of the prior art by providing a solid state power supply circuit for use with cold cathode lighting.

The power supply circuit includes a transformer circuit for converting standard AC input into an electrical output power supplied to a cold cathode light tube, at a high voltage,high current and high frequency. Particularly, the output current is greater than about 30 milliamperes, the output voltage is greater than about 1,000 volts and the frequency is between about 20 KHz and 50 KHz.

One inventive aspect of the solid state power supply circuit is a unique regulating circuit for maintaining output light at a substantially constant predetermined illumination, independent of normal variations of the input voltage.

Another aspect of the invention is the inclusion in a solid state power supply circuit for cold cathode lighting of an overvoltage protection circuit. Damaged light tubes or electrical conditions which result in a voltage level that exceeds a predetermined maximum voltage will automatically shut off power to the cold cathode light tube. Excessive voltage within the circuit is avoided and the potential for accidents is reduced.

Another aspect of the invention is a manual adjustment provided for the solid state power supply circuit for cold cathode lighting. The convenient, simple and inexpensive manual adjustment for the light output uniquely allows on-site adjustment so that effective illumination of a cold cathode light tube can be achieved in the actual operating environment.

A further aspect of the invention is that the solid state power supply circuit can be constructed with a physical size and shape capable of fitting conveniently within a small channel letter. Particularly, a circuit size and shape uniquely found to be desirable for

increased versatility in the construction of a wide variety of channel letters has been achieved.

One aspect of the inventive light box and new solid state power supply is the ability to adjust the light to obtain a desired lighting effect with modern transparencies. For example, adjusting illumination of transparencies in which accurate depiction of skin tones is important, such as transparencies for the advertisement of cosmetics and the like, is advantageously provided. Also, the ability to manually adjust the illumination of a light box appropriately for a particular three-dimension transparency or for various replacement transparencies is advantageously provided for greater adaptability of light boxes for the display of a large variety of transparencies.

A further aspect of the invention is that the solid state power supply circuit can be constructed with a physical size and shape capable of fitting conveniently within a small light box. Particularly, a circuit size and shape custom designed for maximum versatility in constructing light boxes with the power supplies enclosed within the light boxes themselves.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and advantages of the invention will be more fully understood with reference to the following detailed description, claims, and drawings in which like numerals represent like elements and in which:

Figure 1 is a schematic circuit diagram of one embodiment of a solid state power supply circuit according to the present invention;

Figure 2 is a depiction of a solid state circuit of size and shape configuration which has been found to be particularly advantageous with channel letters;

Figure 3 is a schematic depiction of a power supply according to the present invention installed for illuminating a channel letter;

Figure 4 is a schematic depiction of a power supply according to the present in an alternative embodiment for providing power to a large diameter cold cathode light tube installation.

Figure 5 is a depiction of a solid state circuit of size and shape configuration which has been found to be particularly advantageous with light boxes;

Figure 6 is a schematic depiction of a power supply according to the present invention installed for illuminating a light box; and

Figure 7 is a cross-sectional view taken along section line 7-7 of Figure 6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 is a schematic circuit diagram of one embodiment of a solid state power supply circuit 10 for cold cathode lighting according to the present invention. The circuit 10 is useful with an electrical power input at 12, such as 120 volts AC at 60 hertz. Other supply line voltages may be used, such as 240 volts AC, by using circuit components having sufficiently high voltage ratings and appropriate operating characteristics and values for obtaining a desired output voltage and current. The present circuit will be described with respect to 120 volt AC 60 hertz electrical input. For safety, there is a fuse 14 interposed between the input voltage supply 12 and power supply circuit 10. There is a high side rectifier 20 consisting of a four diode full-wave bridge circuit, as schematically shown, for converting A.C. input into D.C. The rectified D.C. is filtered in a filter circuit 30. The combination of the rectifier circuit 20 and the filter circuit 30 converts the input from 120 volts AC RMS into a D.C. voltage corresponding to the peak voltage of the input A.C. wave form. Thus, for 120 VAC RMS, the resulting high D.C. voltage will be about 168 volts D.C. The D.C. voltage will be applied to output transformer 100 at a controlled frequency through the use of power control circuit 90 which includes field effect transistors 92 and 94 which are coupled to the low voltage control side of the power supply circuit 10 through a drive transformer 80.

Turning now to the low voltage side of the control circuit 10, a portion of the input A.C. is rectified and clamped in a voltage dropping circuit 40. A capacitor 41 is used because the low voltage side will be running at a different ground level than the output load ground. A dropping resistor 42 limits the current to the low voltage bridge rectifier circuit 40. A full-wave bridge rectifier, including four diodes, 43, 44, 45, and 46, provides a rectified D.C. voltage which is clamped with a

zener diode 47 down to a fixed voltage of about 12 volts D.C., which is the voltage at which the power is provided for operating a control circuit 50.

The control circuit 50 is preferably a pulse width modulator semiconductor chip, which in this particular embodiment, may comprise, for example, a TL 494CN TWM chip originally manufactured by Texas Instruments. The circuit 50 runs on the fixed voltage from rectifier circuit 40 which is supplied at a pin 51. Internally, the circuit 50 produces a regulated D.C. reference voltage of about 5 volts D.C. The reference voltage is output at pin 52. Control circuit 50 generates controllable frequency output pulses at pins 53 and 54. A frequency control circuit 60 is connected at pins 55 and 56. The value of the resistance 62 between pin 56 and ground and the value of the capacitance 64 between pin 55 and ground controls the frequency of the output pulse at pins 53 and 54. The pulses on pins of 53 and 54 alternate on and off at the frequency determined by resistor 62 and capacitor 64. Thus, pin 53 is high when pin 54 is low.

In the embodiment shown in Figure 1, flip flop circuit 70 is driven by the output pulses of circuit 50 to provide an alternating square wave through a primary coil 81 of coupling or drive transformer 80. The flip flop circuit 70 functions to provide a small alternating voltage at controlled frequency. Primary coil 81 receives the voltage thus generated and drives secondary coils 82 and 84 through drive transformer 80. Voltage produced in coils 82 and 84 activate FETs 92 and 94 alternatingly on and off at the controlled frequency. FET 92 is on when FET 94 is off and vice versa. The high D.C. voltage is converted to AC voltage, which passes through the primary coil of power transformer 100 with a frequency which corresponds to the controlled frequency of pulses of pins 53 and 54 of control circuit 50. Transformer 100 steps up the voltage and provides output

power at the stepped up voltage at terminal 102 and 104. The output power is supplied to cold cathode lighting 105.

Preferably, an efficient high quality output transformer 100 is selected specifically for converting an input voltage of about 168 volts to an output voltage of the desired magnitude for operating in desired length and size of cold cathode light tubing. A controlled frequency of between about 20 and 50 KHz allows the FETs 92 and 94 to effectively and precisely clip off the input voltage as it ramps up to its full 168 volt potential. Thus, the output power can be matched to the power requirements of the particular cold cathode lighting 105 being supplied with power. Maximum illumination efficiency is obtained so that the transformer generates only a small amount of heat to be dissipated. The field effect transistors are selected to have a sufficiently high voltage rating well above the normally expected maximum operating voltage. For example, where the input voltage is expected to be in the range of about 160 to 180 volts, FETs are selected which have a rating of about 260 volts and a low RDS of resistance, such as about .08 ohm RDS on.

Thus, an input voltage of about 110-130 VAC is converted in the rectifier circuit 20 and filter circuit 30 to a D.C. voltage of about 160 to 180 volts D.C. The 160-180 volts D.C. is alternatingly applied to the primary coil of transformed 100 by alternatingly turning the field effect transistors 92 and 94 on and off according to a controlled high frequency. The high frequency A.C. voltage is inductively transformed with output transformer 100 to a desired output voltage and output current corresponding to the power requirements for a given application.

Advantageously, the output power is maintained at a desired constant level regardless of variations or fluctuations in the input voltage. The power supply

circuit 10 is uniquely and advantageously provided with a power regulating circuit 110. The power regulating circuit 110 supplies line voltage through diode 111 to a voltage divider network composed of resistor 112 and 113. A sample voltage is fed to diode 114 where it is clamped at a particular reference voltage with a zener diode 115. A transistor 116 is used to charge a capacitor 117 according to variations in line voltage 12. Thus, when the input voltage 12 is fluctuating, the charge on capacitor 117 will go up or down, correspondingly. The charge on capacitor 117 acts to control transistor 118, turning it on or off to a greater or lesser degree depending on the amount of line voltage variation. The collector of transistor 118 provides a voltage to pin 56 of the control circuit 50. This is accomplished, as shown, by connecting a variable resistor 119 in a parallel circuit with resistor 62 between pin 56 and ground. The effective resistance to ground at pin 56 controls the timing of pulses 53 and 54 of the circuit 50. Thus, by raising the value of resistance 62 at pin 56, the frequency output of circuit 50 at pins 53 and 54 is lowered. Alternatively, by lowering the overall value of resistance at pin 56, the frequency is increased. Increasing the frequency operates FETs 92 and 94 faster, which in turn clips off the rectified high D.C. voltage, thus reducing the output power.

The power regulation circuit 110 thus effectively adjusts the resistance at pin 56, which in turn adjusts the frequency and correspondingly adjusts the power output of transformer 100. Thus, any fluctuations or variations in the input voltage 12, which variations affect the magnitude of the high D.C. voltage, which is provided to transformer 100, are simultaneously compensated for through regulation circuit 110. Higher than desired line voltages at input 12 will effectively increase the operating frequency. This in turn reduces the output current so that output power is maintained

constant of transformer 100. Alternatively, lower than desired line voltage at input 12 will correspondingly reduce the operating frequency which will increase the output current of transformer 100. This will compensate for variations in input line voltage and keep the output power to a given load at a constant value so that the illumination is maintained at a substantially constant illumination level.

In the preferred embodiment of the invention, Applicant has also advantageously utilized a variable resistor 62 that is manually adjustable through a control 65 so that the frequency output of control circuit 50 can be selectably adjusted. Adjustments to the resistor 62 can be advantageously made on site to compensate for tube operating characteristics which vary due to manufacturing tolerances and operating environmental conditions.

Also advantageously in the preferred embodiment, solid state power supply circuit 10 is provided with an overvoltage protection circuit 130. A feedback coil 120 is wound onto the secondary coil of transformer 100. A small number of windings in a feedback coil 120 will act as a voltage sensor which provides a voltage at coil ends 122 and 124 which proportionally corresponds to the output voltage. A corresponding D.C. voltage is produced in a rectifier bridge circuit 131. The corresponding D.C. voltage is supplied to terminal 136 of comparator circuit 132. The output of comparator 132 provides an input via pin 58 to control circuit 50 to turn circuit 50 off thereby providing overvoltage protection for circuit 10. Comparator 132 receives a settable reference voltage at terminal 134. The sensed output voltage at 122 and 124 is rectified and filtered to provide a representative D.C. voltage on comparator terminal 136. The reference voltage 134 is generated using fixed resistor 142 and variable resistor 140 and the voltage from control circuit 50 provided at pin 52. Thus, as long as the representative sensed output voltage at pin 136 stays

below the preset reference voltage at pin 134, the output of comparator 132 at pin 138 stays low. A low state on pin 58 is required to operate control circuit 50. When the output voltage at transformer 100 goes too high, then the representative voltage on sensor coil 120 at ends 122 and 124 will also go high and will cause the representative voltage at pin 136 to exceed reference voltage at 134. This will cause output 138 of the comparator 132 to go high, which in turn will act through pin 58 to internally turn off control circuit 50. Control circuit 50 will not turn on again until the high output voltage situation is corrected and until circuit 50 is re-set by removing power from pin 51 and then reapplying power to pin 51. Turning off the internal mechanism of circuit 50 thus shuts off the frequency response and locks up the circuit 50. This, of course, stops the pulses generated by circuit 50 and effectively turns the output of transformer 100 off until the input voltage at 12 is turned off and turned back on. It will be noted that in the preferred embodiment of protection circuit 130 the reference voltage is selectively settable using a variable resistor 140 in combination with the resistor 142 which is connected to the 5 volt reference produced by control circuit 50 at pin 52.

Figure 2 is a depiction of a solid state power supply circuit 10 having a size and shape configuration which has been found to be particularly advantageous with channel letters. Specifically, a circuit board 16 is enclosed within a housing 15 having a length L at 17, a width W at 18, and a height H at 19. It has been found that small size and light weight is desirable for many useful applications. Particularly, previous magnetic core and wire coil transformers can be replaced with solid state power supplies according to the present invention which weigh less than one fourth as much and still provides sufficient power for equivalent illumination. In a preferred embodiment a solid state

power supply weighing about three pounds (3 lbs) can be used to replace a transformer weighing up to forty-seven pounds (47 lbs). Weight reduction of 75% - 95% is a significant advantage.

Also, it has been found that increased versatile and usefulness in a wide variety of channel letter sizes and fonts can be obtained with a power supply having dimensions of about 6 inches long, about 2 1/2 inches wide, and about 1 1/2 inches high. Power supplies according to the present invention can be constructed with this advantageous size and shape as well other sizes and shapes as may be needed with greater flexibility not previously available with standard core and coil transformers.

Figure 3 is a schematic depiction of a solid state power supply 10 according to the present invention installed for illuminating channel letters 150, 151, and 152. A control device is conveniently accessible through the protective housing 15. For example, in the embodiment shown each of the channel letters can be separately manually adjusted, as with adjustment devices 65, to maximize intensity for differing lengths of cold cathode lighting 105, such as light tubing 153, 154, and 155, as may be used in different letters or to dim newly replaced light bulbs to match the light illumination of the bulbs which have been in service for a period of time. Preferably, over voltage protection is provided so that the channel letters can be used safely both indoors and outdoors. Also preferably, the amount of light is regulated to the gas tube in the channel letter, so that operation of the letters is consistently bright and efficient at various locations and so that fluctuations in line voltage 12 at a given location.

Figure 4 is a schematic depiction of a power supply according to the present invention in an alternative embodiment for providing power to cold cathode lighting 105, which is a very large cold cathode light tube

installation. In the embodiment depicted, a tunnel 156 is continuously illuminated as with a large number of large diameter and long light tubes 157, 158, 159, and 160 which extend along the length of the tunnel. A plurality of high voltage cold cathode light tubes can be connected in series as with 157 and 158. Also, a plurality of separate cold cathode lighting circuits as at 157, 159, and 160 can be powered by a plurality of solid state power supplies 10a, 10b, and 10c. Preferably the power is regulated to compensate for line voltage variations to maintain a desired power output for maximum illumination and/or maximum operating efficiency. Preferably, over voltage protection is provide so that damage to any light tube or any condition effecting the output voltage from the power supply 10 will terminate operation, thus protecting against circuit damage and also against the risk of electrical shocks.

Figure 5 is a depiction of a solid state circuit 10 of size and shape configuration which has been found to be particularly advantageous with light boxes. Advantageously, the size and shape of the power supply can be constructed in a wide variety of shapes and sizes which are not limited by the same limitations existing for magnetic core and wire coil transformers.

Figure 6 is a schematic depiction of a power supply according to the present invention installed for illuminating cold cathode lighting 105 in a light box 162. Advantageously, the power supply 10 is enclosed within the light box 162, which is both aesthetically desirable and convenient for installation purposes. Also, advantageously the manual illumination control device 65 is accessible from outside of the light box.

Figure 7 is a cross-sectional view taken along section line 7-7 of Figure 3.

Other alterations and modifications of the invention will likewise become apparent to those of ordinary skill in the art upon reading the present

disclosure, and it is intended that the scope of the invention disclosed herein be limited only by the broadest interpretation of the appended claims to which the inventors are legally entitled.

CLAIMS:

WHAT IS CLAIMED IS:

1. A solid state power supply circuit for use with cold cathode lighting comprising:

(a) means for converting an input alternating electrical voltage into a high frequency, high voltage output provided to said cold cathode lighting; and

(b) a regulating circuit for maintaining said high voltage output so that a substantially constant predetermined illumination results in said cold cathode lighting, independent of voltage variations of said input alternating electrical voltage.

2. The solid state power supply circuit as in claim 1 further including:

(a) a voltage detection circuit for monitoring said high voltage supplied to said cold cathode lighting and for producing a first voltage signal representing said output voltage;

(b) means for comparing said first signal representing said detected output voltage to a constant reference voltage representing a desired maximum output voltage; and

(c) means responsive to said comparing means to terminate operation of said converting means when said first voltage signal representing said output voltage exceeds said constant reference voltage.

3. The solid state power supply circuit of claim 1 wherein said converting means includes a pulse width modulation circuit for producing said high output voltage at a variable frequency.

4. The solid state power supply circuit of claim 3 and further including means for controlling said frequency of said high output voltage due to variations in said input A.C. voltage.

5. The solid state power supply circuit of claim 3 and further including means for manually controlling said frequency of said high voltage output.

6. The solid state power supply circuit of claim 5 wherein said control means includes a variable resistor.

7. The solid state power supply of claim 6 wherein said cold cathode lighting to which said solid state power supply provides power comprises a channel letter.

8. The solid state power supply of claim 6 wherein said cold cathode lighting to which said solid state power supply provides power comprises large cold cathode light tubing having a diameter greater than about 25mm.

9. The solid state power supply of claim 6 wherein said cold cathode lighting to which said solid state power supply provides power comprises a light box.

10. A solid state power supply circuit for use with cold cathode lighting including:

(a) a solid state transforming circuit for converting an AC voltage input into a high frequency, high voltage output, which output voltage is supplied to said cold cathode lighting for illumination of said lighting; and

(b) an overvoltage protection circuit connected to said transforming circuit for disabling said transforming circuit when said high output voltage exceeds a preset maximum voltage.

11. A solid state power supply circuit as in claim 10 wherein said overvoltage protection circuit includes:

(a) an output voltage detection circuit coupled to said transforming circuit for detecting said high output voltage supplied to said cold cathode lighting and for producing a test voltage representing said detected high output voltage;

(b) a comparator connected to said voltage detection circuit for comparing said test voltage representing said detected high output voltage to a constant reference voltage representing a desired maximum output voltage; and

(c) a shut-off circuit responsive to said comparator to shut off said transforming circuit when said test voltage representing said high output voltage exceeds said constant reference voltage representing said desired maximum voltage.

12. A solid state power supply circuit as in claim 11 wherein said constant reference voltage representing said desired maximum output voltage is produced by an adjustable voltage source.

13. The solid state power supply circuit of claim 10 wherein said transforming circuit includes a pulse width modulation circuit for producing an output signal at a variable frequency.

14. The solid state power supply circuit of claim 13 and further including means for controlling said frequency of said output signal due to variations in said input A.C. voltage.

15. The solid state power supply circuit of claim 10 and further including means for manually controlling said frequency of said output signal.

16. The solid state power supply circuit of claim 15 wherein said control means includes a variable resistor.

17. The solid state power supply circuit of claim 16 further comprising a regulating circuit for maintaining said high voltage output at a constant predetermined current level independent of voltage variations of said input voltage.

18. The solid state power supply circuit of claim 10 further comprising a regulating circuit for maintaining said high voltage output at a constant predetermined voltage level independent of voltage variations of said input voltage.

19. The solid state power supply of claim 18 wherein said cold cathode lighting for which said solid state power supply is useful comprises a channel letter.

20. The solid state power supply of claim 18 wherein said cold cathode lighting for which said solid state power supply is useful comprises a large cold

cathode light tubing having a diameter greater than about 25mm.

21. The solid state power supply of claim 18 wherein said cold cathode lighting for which said solid state power supply is useful comprises a light box.

22. A light box for illuminating transparencies comprising:

(a) a frame for supporting a transparency to be illuminated along a frontal plane from behind;

(b) a tubular cold cathode light tube supported within said frame in a plane substantially parallel to said frontal plane and spaced apart therefrom by a short distance; and

(c) a solid state power supply circuit connectable to an input AC electrical voltage including means for converting said input voltage to a high frequency, high voltage output power and operatively connected for supplying said output power to said cold cathode light tube and including a regulating circuit for maintaining said output power at a constant predetermined power unaffected by variations of said input AC electrical voltage.

23. A light box as in claim 22 further comprising an overvoltage protection circuit operatively connected to said solid state power supply circuit for automatically disabling said solid state power supply circuit when said high voltage of said output power exceeds a pre-set maximum voltage.

24. A light box as in claim 23 further comprising an overvoltage protection circuit operatively connected to said solid state power supply circuit for automatically disabling said solid state power supply circuit when said high voltage of said output power exceeds a pre-set maximum voltage.

25. A light box as in claim 22 further comprising:

(a) a power adjusting circuit operatively connected to said solid state power supply circuit and responsive to a variable resistance for varying said output power supplied to said cold cathode light tube; and

(b) a manual adjustment device attached to said light box frame accessible from outside of said light box and operatively connected to said variable resistance for selectably adjusting said variable resistance so that said output power supplied to said cold cathode light tube is correspondingly adjusted.

26. A light box for illuminating transparencies comprising:

(a) a frame for supporting a transparency to be illuminated along a frontal plane from behind;

(b) a tubular cold cathode light tube supported within said frame in a plane substantially parallel to said frontal plane and spaced apart therefrom by a short distance;

(c) a solid state power supply circuit connectable to an input electrical current and operatively connected to said cold cathode light tube supplying high frequency, high voltage and high current output power thereto and including an overvoltage protection circuit operatively connected to said solid state power supply circuit for automatically disabling said solid state power supply circuit when said high voltage of said output power exceeds a pre-set maximum voltage.

27. A light box as in claim 26 further comprising:

(a) a power adjusting circuit operatively connected to said solid state power supply circuit and responsive to a variable resistance for varying said output power supplied to said cold cathode light tube; and

(b) a manual adjustment device attached to said light box frame accessible from outside of said light box and operatively connected to said variable resistance for selectably adjusting said variable resistance so that said output power supplied to said cold cathode light tube is correspondingly adjusted.

28. A light box for illuminating transparencies comprising:

(a) a frame for supporting a transparency to be illuminated along a frontal plane from behind;

(b) a tubular cold cathode light tube supported within said frame in a plane substantially parallel to said frontal plane and spaced apart therefrom by a short distance;

(c) a solid state power supply circuit connectable to an input electrical current and operatively connected to said cold cathode light tube supplying high frequency high voltage and high current output power thereto and including:

(i) a power adjusting circuit operatively connected to said solid state power supply circuit and responsive to a variable resistance for varying said output power supplied to said cold cathode light tube; and

(ii) a manual adjustment device attached to said light box frame accessible from outside of said light box and operatively connected to said variable resistance for selectably adjusting said variable resistance so that said output power supplied to said cold cathode light tube is correspondingly adjusted.

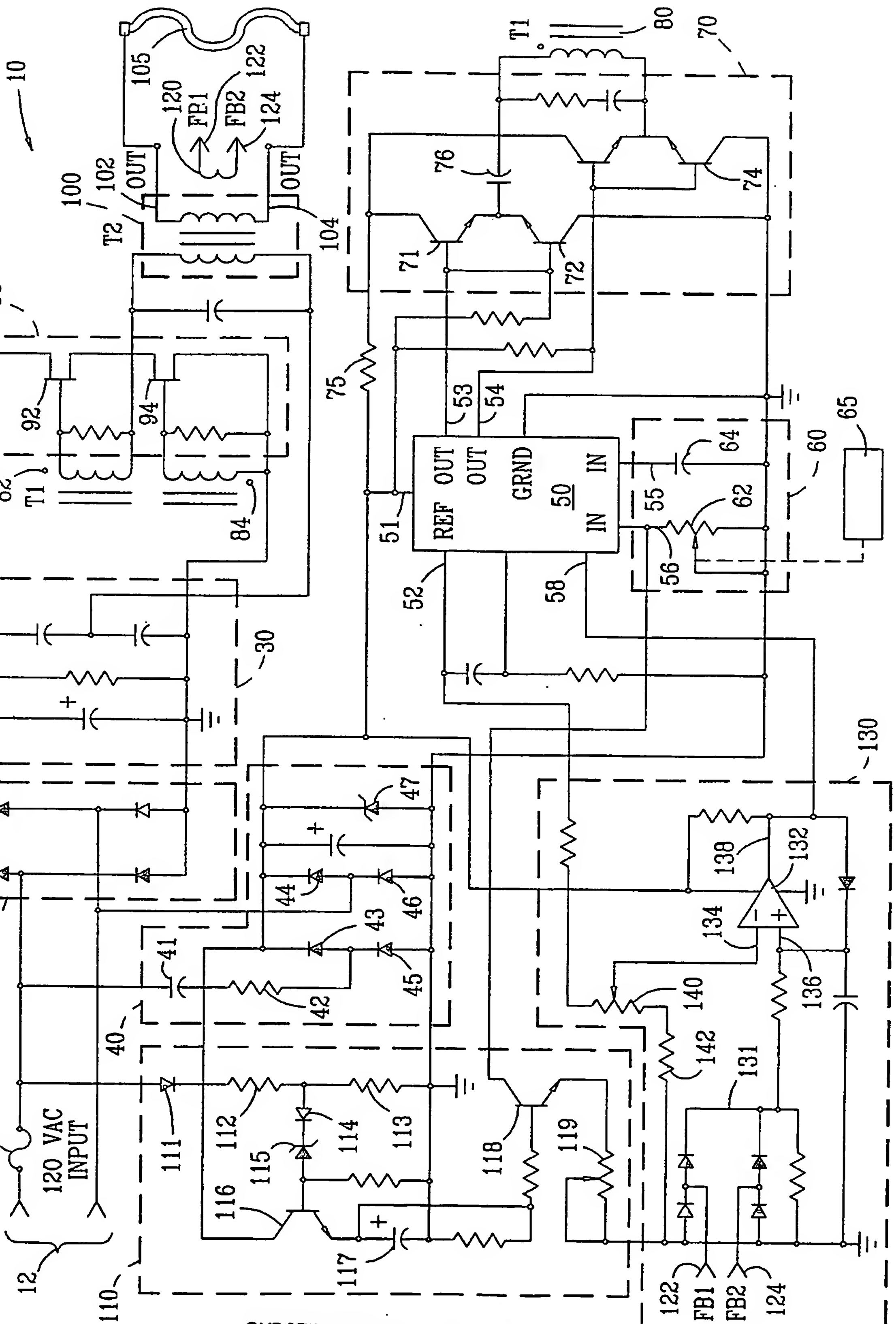


FIG. 1

FIG. 2

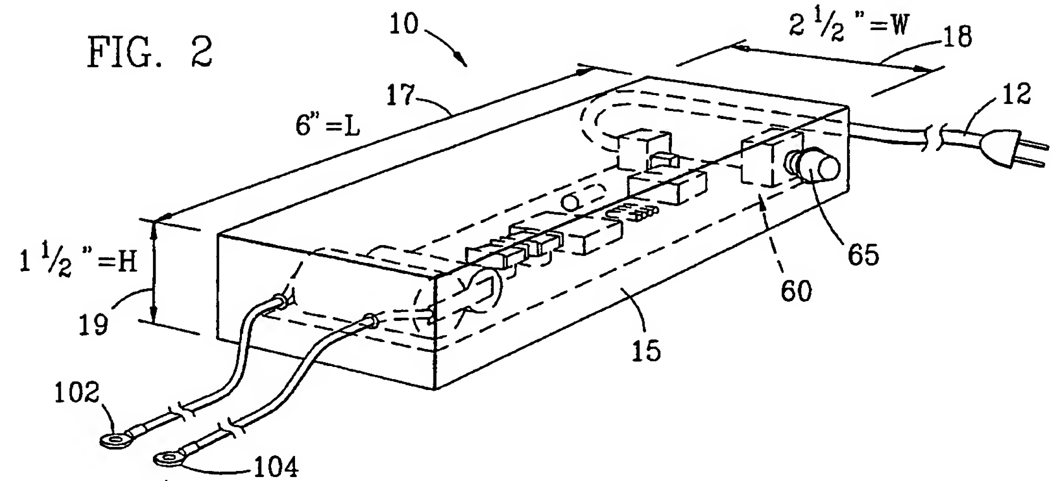
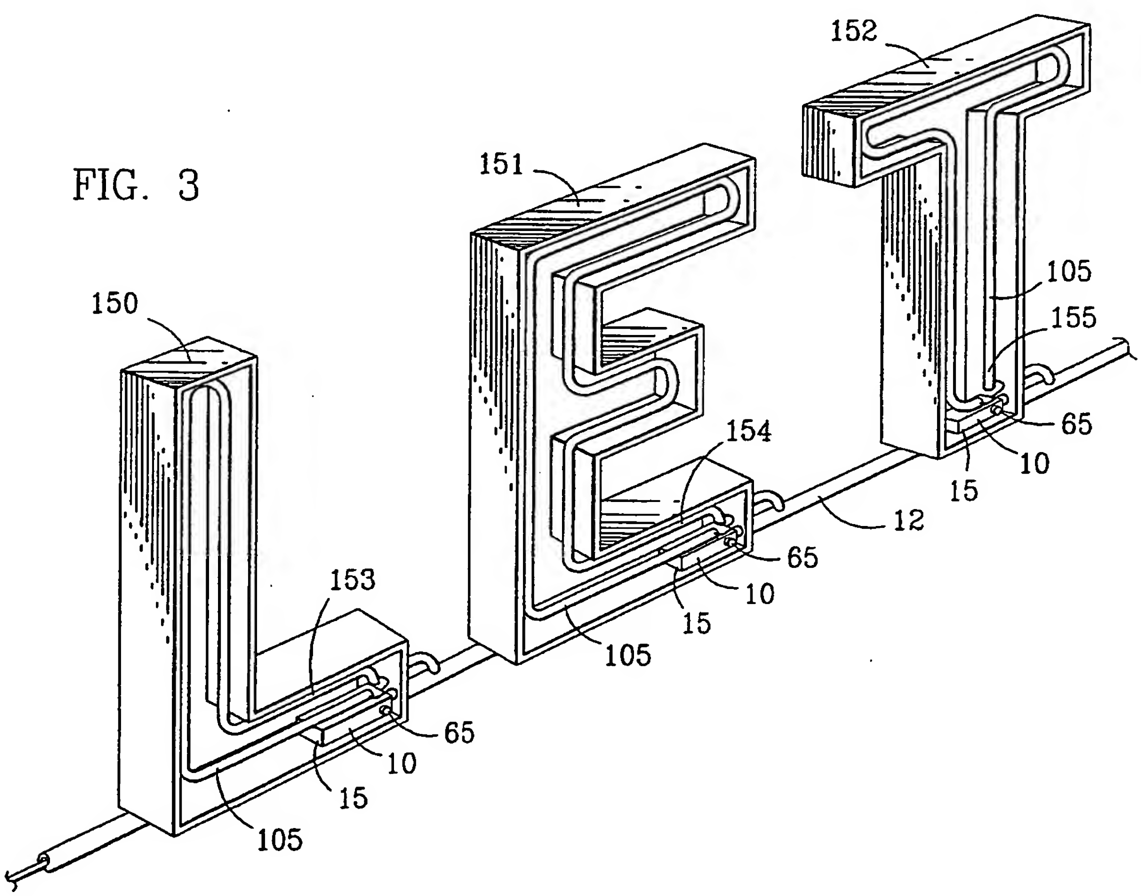

10
2 1/2 "=W
18
17
12
6"=L
1 1/2 "=H
65
60
19
15
102
104

FIG. 3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153
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65
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105

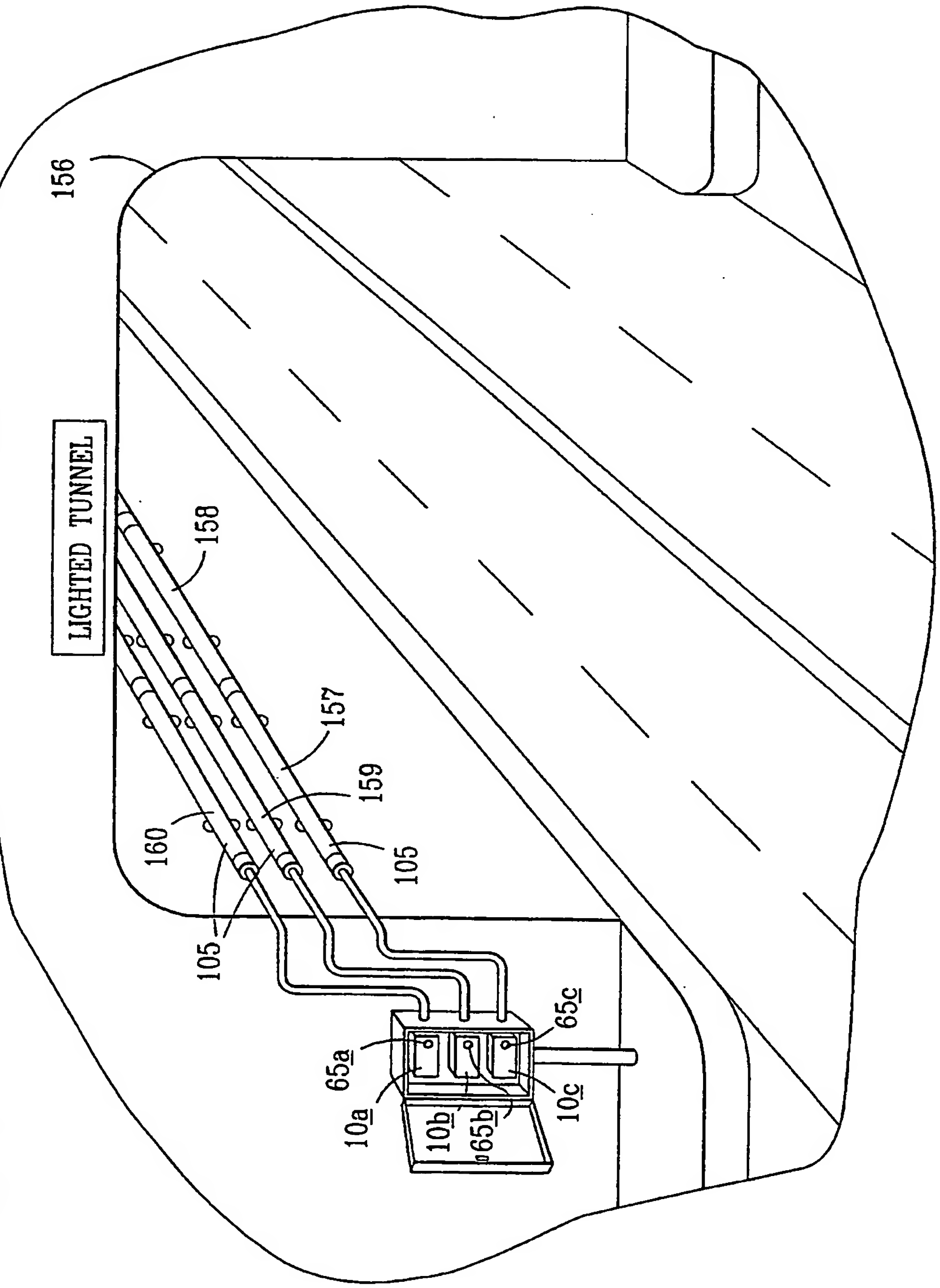
156
LIGHTED TUNNEL
158
157
159
160
105
105
105
65a
65c
10a
10b
65b
10c

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/14300

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :HO5B 37/02
US CL :315/209R, 224, 219, 291, 307, 308, DIG 4, DIG 5, DIG 7 ;362/812
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 315/209R, 224, 219, 291, 307, 308, DIG 4, DIG 5, DIG 7 ;362/812

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US, A 5,051,665 (Garrison et al.) 24 September 1991, Note column 5, lines 33-49	1-8,10-18 -------------- 9, 19-28

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 MARCH 1995	30 MAR 1995

Name and mailing address of the ISA/US	Authorized officer
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